COMPARISON OF AERODYNAMIC ROUGHNESS (Z-0) VALUES FROM WIND MEASUREMENTS AND SRL RADAR; WESTERN U.S. AND NAMIBIAN DESERTS:

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Aerodynamic roughness (z-0) is the height above a surface at which a wind profile assumes zero velocity. It is an important parameter in studies of atmospheric circulation and aeolian sediment transport and it is strongly influenced by size and spacing of surface roughness elements. Its value, in meters, typically is derived from field measurements of wind velocity profiles. Because of complexities in field logistics, z-0 measurements exist for relatively few localities. If z-0 can be estimated with radar, large areas can be mapped quickly and repeatedly. Z-0 and the radar backscatter coefficient s-0 (in dB) are both functions of submeter topography and correlations of z-0 with s-0 have been developed from aircraft radar (AIRSAR) data [1]. The Spaceborne Radar Laboratory (SRL) has allowed testing of similar correlations for orbital radar data. SRL is a multiwavelength, multipolarization imaging radar system flown on the Space Transportation System ("shuttle") Endeavour in April (SRL-1) and October (SRL-2), 1994. SRL obtained digital radar data in three wavelengths: L-band (l =24 cm), C-band (l =5.6 cm), and X-band (l =3 cm, not used in this study). The L- and C-band systems transmited and received in horizontally (H) or vertically (V) polarized modes, to provide a scattering matrix of HH, VV, VH, and HV combinations.

SRL data for sites in Death Valley, California, Lunar Lake, Nevada, and Gobabeb, Namibia, were correlated with wind data and were compared with previous AIRSAR derived z-0 values. Correlation coefficients between s-0 and z-0 range from 0.87 for L-HV to 0.99 for L-HH and C-HV, which compare favorably with previous studies. Z-0 maps derived from SRL data demonstrate the potential of orbital radar systems for charting aerodynamic roughness values over large, relatively flat areas of vegetation-free land.

Field Sites: Test sites were selected to meet several criteria. They have relatively homogeneous surfaces covering broad areas and have slopes generally less than 4° in order to reduce effects on s-0 by local incidence angles. They have little or no vegetation in order to minimize radar volume scattering effects, to ensure that z-0 was controlled primarily by topographic roughness, and to eliminate displacement height factors.

Death Valley, California: Three Death Valley sites, all on alluvial fans of different ages and surface roughnesses, were used in previous AIRSAR studies [1,2,3] and were also targeted by the SRL. The Golden Canyon site is on a vegetation-free part of a recent fan with bar-and-channel topography of 20-50 cm relief. Channels partly filled with sand and silt are separated by gravel-to-cobble bars with a sandy-silt matrix. Stovepipe Wells study area is a flat to gently undulating surface of gravely sands on the distal part of another fan. Channels 10-20 cm deep and 1-2 m wide cut into a surface partly paved with wind abraded rocks. Kit Fox test site is about 3 km east-southeast of Stovepipe Wells and on the same alluvial fan. Cobbly gravels imbedded in a mobile sandy matrix are interupted by numerous sand or granule floored channels up to 10 cm deep and 2 m wide which drain toward the west.

Lunar Lake, Nevada: Also used in AIRSAR studies [1], Lunar Lake is a dry playa within the Lunar Crater volcanic field in Nye County, Nevada. Its surface consists of 14 square km of silty clay with patches of gravel around the edges. When field work was conducted, the surface was fractured with 15 mm deep desiccation cracks spaced at ~20 cm. The playa surface is smoother from north to south and the desiccation cracks change abruptly to a spacing of 2-9 cm with depths of ~3 mm. Two wind measuring sites were set on the dry lake bed, one near the center of the playa and another near its SW edge.

Gobabeb, Namibia: This site is located on the northern margin of the Namib Sand Sea, just south of the Kuiseb River. Near the small settlement of Gobabeb, large south-to-north-trending complex linear dunes of the sand sea are irregularly spaced over a pre-dune bedrock surface. Interdune areas up to 4 km wide are covered by a thin gravel-to-granule lag with rare simple linear dunes or irregular barchans. Bedrock is exposed in scattered patches and vegetation is virtually absent. Topographic relief of interdune surfaces is less than 1.5 m and slopes are less than 2° from horizontal [4].

Aerodynamic roughness and radar backscatter: Preliminary z-0 to s-0 correlations were determined from Death Valley and Mojave Desert AIRSAR sites [1,2]. L-band HV polarization produced the best fit (R=0.81) which is attributed to the sensitivity of ~24 cm wavelengths to surface roughness elements of similar scale. Compared with lower altitude airborne radars, orbital radars cover larger areas with more constant incidence angles and are more suitable for z-0 mapping. Considering both AIRSAR and SRL data, cross polarized L-band (L-HV) appears to be the best combination for mapping z-0 values although relatively good coefficients (>0.80) for other wavelengths and polarizations are probably acceptable.

Aerodynamic roughness maps for Death Valley, Lunar Lake, and Namibia have been produced using SRL L-band radar. Data are "multilook" filtered to reduce radar speckle and to produce square pixels with a spatial resolution of 25 m/pixel. To produce aerodynamic roughness maps in meters, z-0 is calculated as

$$z\text{-}0 = 10^{((s\text{-}0-m0)/m1)}$$

in which m0 and m1 are empirical coefficients previously derived for each AIRSAR radar channel (wavelength and polarization) and field wind data [1]. Resulting z-0 values for each pixel are sorted into half order-of-magnitude bins. Output is displayed as a maplike color-coded or gray-scaled image in which each color or gray corresponds to a z-0 bin within the range of 0.00001 m to 0.1 m. These values are typical for flat geologic surfaces ranging from smooth playas to rugged lava flows. Radar returns from areas of steep relief are dominated by local slope effects and are eliminated using information from topographic maps.

Results: The aerodynamic roughness ranges predicted on maps derived from SRL data are all within, or very close to, values calculated from field-measured wind profiles.

At Death Valley, the Stovepipe Wells radar map produced an aerodynamic roughness range of mostly from 0.001 m to 0.005 m compared to a wind-mast determined mean z-0 value of 0.00347 m. At the nearby Kit Fox site, SRL radar data predicted a z-0 range of from 0.0005 m to 0.005 m whereas two separate wind stations measured z-0 values of 0.000850 m and 0.000696 m. Further south at Golden Canyon, radar data indicated an aerodynamic roughness range of 0.0005 m to 0.05 m and corresponding wind measurements, collected over a period of directional shifts, yielded values of 0.0106 m, 0.00126 m, and 0.002450 m.

At Lunar Lake, Nevada, radar-derived aerodynamic roughness estimates ranged from 0.0001 m to 0.001 m which bracketed values of 0.000182 m and 0.000126 m derived from wind stations at two locations on the playa floor.

In Namibia, the Gobabeb test site comprised two separate wind stations, one on gravel lag and another on a thin sand sheet, established on interdune surfaces during previous aeolian studies [4]. Radar derived z-0 values range from 0.0001 m to 0.0005 m over the gravel target and from 0.00001 m to 0.0001 m over the sand sheet and are in excellent agreement with field-measured z-0 values of 0.00042 m and 0.00004 m, respectively. Sands along lower dune flanks produce radar derived z-0 values of 0.00005 m to 0.0005 m, an order of magnitude smoother than vallues for Death Valley dunes where coarse sand and ripples are found.

SRL has provided the opportunity to test established z-0 to s-0 correlations with orbital radar data and showed maximum correlations (r = 0.99) for L-HH and C-HV data. These results suggest that radar data obtained from orbit can be used to map z-0 values over large areas, which in turn would allow input of z-0 into models of aeolian processes and atmospheric circulation.

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